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(54) EXHAUST EMISSION CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINES

ABGASKONTROLLVORRICHTUNG FÜR BRENNKRAFTMASCHINEN

DISPOSITIF ANTIPOLLUTION POUR MOTEURS A COMBUSTION INTERNE

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- **PATENT ABSTRACTS OF JAPAN vol. 1995, no. 02, 31 March 1995 (1995-03-31) & JP 06 307232 A (TOYOTA MOTOR CORP), 1 November 1994 (1994-11-01)**
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Descripti n

TECHNICAL FIELD

[0001] The present invention relates to an exhaust purifier for use in an internal combustion engine having in an exhaust path thereof a catalyst device (NOx catalyst) which occludes NOx contained in exhaust at a lean air-fuel ratio; i.e., in an oxygen-excessive atmosphere, and which releases occluded NOx at a stoichiometric air-fuel ratio or a rich air-fuel ratio; i.e., in a low-oxygen-concentration atmosphere.

BACKGROUND ART

[0002] Recently, in order to improve fuel economy, a lean-burn engine enabling combustion at a lean air-fuel ratio has been put into practical use. The lean-burn engine involves a problem in that a conventional three-way catalytic converter fails to sufficiently purify NOx in exhaust during lean combustion due to its purification characteristics. Thus, recently there has been employed, for example, a catalyst device (NOx catalyst) for purifying NOx in exhaust during lean combustion through occlusion of NOx contained in exhaust.

[0003] The NOx catalyst is known to purify NOx contained in exhaust in an oxygen-excessive atmosphere (at a lean air-fuel ratio) through occlusion of NOx onto a catalyst and to release occluded NOx when oxygen concentration lowers (at a stoichiometric air-fuel ratio or a rich air-fuel ratio). Specifically, in an oxygen-excessive atmosphere, the NOx catalyst produces a nitrate from NOx contained in exhaust to thereby occlude NOx. By contrast, in a low-oxygen-concentration atmosphere, the NOx catalyst causes the nitrate occluded on the NOx catalyst and CO contained in exhaust to react with each other, thereby generating a carbonate and releasing NOx.

[0004] In an oxygen-excessive atmosphere during lean operation, the NOx catalyst occludes NOx thereon. However, when the NOx catalyst becomes saturated with occluded NOx after continuation of lean operation, most NOx contained in exhaust is emitted into the atmosphere. Thus, before the NOx catalyst becomes saturated with NOx, the air-fuel ratio is switched to a stoichiometric air-fuel ratio or a rich air-fuel ratio so as to lower the oxygen concentration of exhaust, whereby NOx is released and reduced to thereby restore the NOx occlusion capability of the NOx catalyst. According to a technique disclosed in, for example, Japanese Patent Application Laid-Open (*kokai*) No. 7-166913, when the air-fuel ratio of the engine is switched to a stoichiometric air-fuel ratio or a rich air-fuel ratio in order to restore the NOx occlusion capability of the NOx catalyst, the air-fuel ratio is gradually changed to a stoichiometric air-fuel ratio or a rich air-fuel ratio to thereby release and reduce NOx while suppressing a torque shock acting on the engine.

[0005] When NOx is released and reduced through switching the air-fuel ratio of the engine to a stoichiometric air-fuel ratio or a rich air-fuel ratio (CO is generated and supplied into exhaust; i.e., to the NOx catalyst) in order to restore the NOx occlusion capability of the NOx catalyst, a portion of supplied CO is consumed for releasing occluded NOx, and residual CO is consumed for reducing released NOx. When a ratio at which NOx is reduced by means of reducers, such as the residual CO and HC, coincides with that at which NOx is released, release of NOx and CO into the atmosphere can be suppressed.

[0006] However, the technique disclosed in the above publication encounters difficulty in establishing coincidence between a ratio at which NOx is reduced and that at which NOx is released. This is because the NOx occlusion capability restoration performance of the NOx catalyst; i.e., the releasability of the NOx catalyst with respect to occluded NOx (NOx-releasing rate), depends on the form and amount of a catalytic component carried on the NOx catalyst.

[0007] Document JP 6307232 discloses an engine comprising a NOx adsorption-reduction catalyst, wherein during a rich operation of the engine, H_2 is supplied to the exhaust to desulpusite the NOx catalyst.

[0008] In the case of employment of an NOx catalyst having improved NOx occlusion capability restoration performance, the NOx-releasing rate, or the rate,at which NOx is released from the NOx catalyst, is also improved. As a result, the amount of NOx present in exhaust gas and to be reduced by means of reducers tends to become smaller than that of NOx to be released (NOx to be reduced < NOx to be released). Thus, residual NOx which remains in exhaust gas without being reduced is emitted into the atmosphere. By contrast, in the case of employment of an NOx catalyst having limited NOx occlusion capability restoration performance, the amount of NOx to be reduced tends to become greater than that of NOx to be released (NOx to be reduced > NOx to be released). Thus, reducers (CO, etc.) remain in exhaust gas and are released into the atmosphere.

[0009] Generally, as the air-fuel ratio of the engine approaches the rich side (as the amount of CO increases), the NOx-releasing rate increases. Thus, when the air-fuel ratio is shifted toward a stoichiometric air-fuel ratio or a rich air-fuel ratio as described in the above publication, the NOx-releasing rate begins to increase at a near stoichiometric air-fuel ratio, at which the amount of CO begins to increase; thus, the amount of NOx to be released from the NOx catalyst increases. However, the amount of reducers (residual CO, HC, etc. which have not contributed to release of NOx) is not sufficient for reducing the increased amount of released NOx. As a result, released NOx remaining in exhaust gas is released into the atmosphere without being reduced.

[0010] A conceivable solution for this problem is to increase the amount of reducers through enriching the air-fuel ratio of the engine. In this case, since the amount

of CO serving as a reducer also increases, the amount of NOx to be released increases. Therefore, in actuality, the above-mentioned relation "NOx to be reduced < NOx to be released" remains unchanged. As a result, residual NOx which remains in exhaust without being reduced is released into the atmosphere, constituting failure to suppress emission of NOx.

[0011] Accordingly, the technique disclosed in the above publication encounters difficulty in establishing substantial coincidence between the amount of NOx to be reduced and that of NOx to be released and thus involves a problem in that exhaust gas characteristics are impaired during release of NOx from the catalyst and reduction of released NOx.

[0012] The present invention has been accomplished in view of the foregoing, and an object of the present invention is to provide an exhaust purifier for use in an internal combustion engine capable of reliably reducing NOx released from a catalyst device (NOx catalyst).

DISCLOSURE OF THE INVENTION

[0013] According to an exhaust purifier of the present invention for use in an internal combustion engine, when the exhaust air-fuel ratio of the engine is switched from a lean air-fuel ratio to a stoichiometric air-fuel ratio or a rich air-fuel ratio, reducer-supplying means supplies additional HC as a reducer for reducing NOx released from an NOx catalyst device so as to reduce NOx released from the catalyst device without impairing exhaust gas characteristics.

[0014] Since NOx released from the NOx catalyst device is reduced by means of the supplied reducer, NOx is not released into the atmosphere, thereby suppressing impairment in exhaust gas performance.

[0015] In the case of a cylinder-injection-type internal combustion engine having an injection valve for directly injecting fuel into a combustion chamber, the reducer-supplying means preferably injects fuel during an expansion stroke or an exhaust stroke subsequent to main injection effected by the injection valve (injection during an intake stroke or injection during a compression stroke).

[0016] Thus, NOx released from the catalyst device can be reliably reduced without need of a complicated device.

[0017] According to the exhaust purifier of the present invention for use in an internal combustion engine, when NOx-releasing means is operated to create a low-oxygen-concentration exhaust atmosphere in order to release NOx from an NOx catalyst, the reducer-supplying means additionally supplies a reducer for reducing NOx released into an exhaust path, at predetermined timing during operation of the NOx-releasing means, thereby reducing NOx released from the NOx catalyst without impairment of exhaust gas characteristics.

[0018] Since NOx released from the catalyst device is reduced by means of the supplied reducer, NOx is not released into the atmosphere, thereby suppressing impairment in exhaust gas performance.

[0019] The additional HC supplied as a reducer by the reducer-supplying means does not increase the NOx releasing rate abruptly. Thus, in the case of, for example, a cylinder-injection-type internal combustion engine, the reducer-supplying means preferably assumes the form of fuel control for injecting additional fuel during an expansion stroke or an exhaust stroke subsequent to main injection (injection during an intake stroke or injection during a compression stroke) or assumes the form of an injection valve dedicated to injection of a reducer and adapted to inject fuel into an exhaust path.

[0020] The NOx catalyst occludes NOx contained in exhaust when exhaust gas assumes a lean air-fuel ratio; i.e., the form of an oxygen-excessive atmosphere. The NOx catalyst releases occluded NOx when exhaust gas assumes a stoichiometric air-fuel ratio or a rich air-fuel ratio; i.e., the form of a low-oxygen-concentration atmosphere. The reducer-supplying means operates at a predetermined period of time when exhaust gas assumes a near stoichiometric air-fuel ratio as a result of operation of the NOx-releasing means. In the case of an engine having an injection valve for injecting fuel directly into a combustion chamber, the reducer-supplying means controls operation of the injection valve so as to additionally supply a reducer.

[0021] The NOx-releasing means has a regenerative function for establishing a rich air-fuel ratio in exhaust gas for a first predetermined period of time and subsequently establishing a near stoichiometric air-fuel ratio for a second predetermined period of time when NOx occluded on the NOx catalyst is to be released. The reducer-supplying means operates when the NOx-releasing means causes switching of an air-fuel ratio in exhaust gas to a rich air-fuel ratio. The exhaust purifier includes deterioration-detecting means for detecting the degree of deterioration of the NOx catalyst, and correction means for making correction so as to prolong the second predetermined period of time associated with the regenerative function of the NOx-releasing means or so as to shorten the operating period of time of the reducer-supplying means as the degree of deterioration of the NOx catalyst detected by the deterioration-detecting means increases.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 is a schematic view of an internal combustion engine having an exhaust purifier according to an embodiment of the present invention; FIG. 2 is a block diagram of the exhaust purifier; FIG. 3 are graphs representing a basic NOx-releasing behavior; FIG. 4 is a flowchart showing the state of release of NOx effected by the exhaust purifier; FIG. 5 is a flowchart showing the state of release of NOx effected by the exhaust purifier; FIG. 6 is a timing chart showing the state of release of NOx; FIG. 7 is a timing chart showing the state of release

of NOx; FIG. 8 is a chart showing the relationship during NOx purge between rich-mode continuation time and NOx-releasing rate; FIG. 9 is a chart showing the relationship between lean-mode continuation time and amount of emitted NOx; FIG. 10 is a chart showing the relationship between lean-mode continuation time and HC emission value; FIG. 11 is a chart showing dead time during NOx purge (during shift to rich state); FIG. 12 is a chart explaining optimum lean-mode continuation time; and FIG. 13 is a chart showing the effect of catalyst deterioration on NOx-releasing rate.

BEST MODE FOR CARRYING OUT THE INVENTION

[0023] Embodiments of the present invention will next be described in detail with reference to the drawings.

[0024] A cylinder-injection-type straight 4-cylinder gasoline engine (cylinder-injection engine) 1 will be described as example of a multiple-cylinder cylinder-injection-type internal combustion engine. In the cylinder-injection engine 1, fuel injection during an intake stroke (intake-stroke injection mode) or fuel injection during a compression stroke (compression-stroke injection mode) can be performed through, for example, switching of combustion modes (operation modes). The cylinder-injection engine 1 enables operation at a stoichiometric air-fuel ratio (stoichiometry), operation at a rich air-fuel ratio (rich-air-fuel-ratio operation), and operation at a lean air-fuel ratio (lean-air-fuel-ratio operation). Particularly, in the compression-stroke injection mode, the cylinder-injection engine 1 can be operated at an ultralean air-fuel ratio, which is greater than the air-fuel ratio of a lean-air-fuel-ratio operation performed during an intake stroke.

[0025] As shown in FIG. 1, a cylinder head 2 of the cylinder-injection engine 1 includes spark plugs 3 mounted thereon for individual cylinders and solenoid-type fuel injection valves 4 mounted thereon for individual cylinders. The injection port of the fuel injection valve 4 opens into a combustion chamber 5 so that fuel is injected directly into the combustion chamber 5 from the fuel injection valve 4. A piston 7 is supported in a cylinder 6 of the cylinder-injection engine 1 in a vertically slidable manner. A hemispherically depressed cavity 8 is formed on the top surface of the piston 7. The cavity 8 is adapted to generate a reverse tumble flow, which is directed clockwise in FIG. 1.

[0026] The cylinder head 2 has intake ports formed therein in a substantially vertical direction for individual cylinders. The corresponding ends of an intake manifold 9 are connected to the intake ports in a communicating manner. The cylinder head 2 has exhaust ports formed therein in a substantially horizontal direction for individual cylinders. The corresponding ends of an exhaust manifold 10 are connected to the exhaust ports in a communicating manner. An unillustrated EGR device is disposed on the exhaust manifold 10.

[0027] An exhaust pipe (exhaust path) 11 is connected to the exhaust manifold 10 of the engine 1. An unillustrated muffler is connected to the exhaust'pipe 11 via a small-sized three-way catalyst 12 located in the vicinity of the engine 1, and via an exhaust-purifying catalyst device 13. A high-temperature sensor 14 for detecting exhaust temperature is disposed on the exhaust pipe 11 at a portion between the three-way catalyst 12 and the exhaust-purifying catalyst device 13 and immediately upstream of the exhaust-purifying catalyst device 13; i. e., immediately upstream of an NOx catalyst 15, which will be described later.

[0028] The exhaust-purifying catalyst device 13 includes an NOx catalyst 15 (catalyst device) and a three-way catalyst 16. When exhaust gas assumes a lean air-fuel ratio; i.e., the form of an oxygen-excessive atmosphere, the NOx catalyst 15 purifies NOx contained in exhaust through occlusion of NOx onto the catalyst. When the oxygen concentration of exhaust lowers until exhaust gas assumes a stoichiometric air-fuel ratio or a rich air-fuel ratio, the NOx catalyst 15 releases occluded NOx. The three-way catalyst 16 has a three-way function capable of purifying exhaust of CO, HC, and NOx in an atmosphere having a stoichiometric air-fuel ratio. The three-way catalyst 16 is disposed downstream of the NOx catalyst 15 and is adapted to reduce a portion of NOx released from the NOx catalyst 15 which remains unreduced. Notably, the structure of the exhaust-purifying catalyst device 13 is not limited to that of the above-described embodiment in terms of arrangement and function of the catalyst, insofar as the exhaust-purifying catalyst device 13 includes at least one NOx catalyst 15.

[0029] The NOx catalyst 15 has the NOx release-and-reduction function of once occluding NOx in an oxidizing atmosphere and releasing NOx and reducing the same to N_2 (nitrogen) in a reducing atmosphere in which a predominant amount of CO is present. Specifically, the NOx catalyst 15 includes noble metals, such as platinum (Pt) and palladium (Pd), serving as catalysts, and alkali metals, such as barium (Ba), and alkaline-earth metal, serving as occludent substances. An NOx sensor 17 for detecting the NOx concentration of exhaust is disposed downstream of the exhaust-purifying catalyst device 13.

[0030] An electric throttle valve 21 of a drive-by-wire (DBW) type is connected to the intake manifold 9. A throttle position sensor 22 for detecting throttle opening θth is disposed on the throttle valve 21. A crank angle sensor 23 for detecting a crank angle is disposed on the engine 1. The crank angle sensor 23 can detect engine speed Ne.

[0031] A vehicle is equipped with an electronic control unit (ECU) 31. The ECU 23 includes an input-output unit; a storage unit for storing a control program, a control map, etc.; a central processing unit; a timer; and counters. The ECU 31 performs overall control of the exhaust purifier of the present embodiment as well as overall control of the cylinder-injection engine 1. Information detected by various sensors is input to the ECU

31. On the basis of the input information, the ECU 31 determines a fuel injection mode, the amount of fuel to be injected, and ignition timing, and operates and controls the fuel injection valves 4, the spark plugs 3, etc.

[0032] In the cylinder-injection engine 1, intake air which flows into the combustion chamber 5 from the intake manifold 9 forms a reverse tumble flow. Fuel is injected at or after a middle point of a compression stroke, and a small amount of fuel is collected only in the vicinity of the spark plug 3, which is disposed at the center of a top portion of the combustion chamber 5, through utilization of the reverse tumble flow. Thus, a very lean air-fuel ratio is established at a portion of the combustion chamber 5 located away from the spark plug 3. Through establishment of a stoichiometric air-fuel ratio or a rich air-fuel ratio only in the vicinity of the spark plug 3, stable stratified-charge combustion (stratified-charge ultralean combustion) is established to thereby reduce fuel consumption.

[0033] When high output is to be obtained from the cylinder-injection engine 1, fuel is injected from the fuel injection valve 4 during an intake stroke so as to homogenize the mixture within the entire combustion chamber 5 to a stoichiometric air-fuel ratio or a lean air-fuel ratio, followed by pre-mixture combustion. In this case, since higher output is obtained at a stoichiometric air-fuel ratio or a rich air-fuel ratio, fuel is injected at such timing that fuel is atomized or vaporized sufficiently, thereby yielding high output efficiently.

[0034] On the basis of throttle opening θth received from the throttle position sensor 22 and engine speed Ne received from the crank angle sensor 23, the ECU 31 obtains a target cylinder pressure corresponding to an engine load; i.e., target mean effective pressure Pe. Further, through reference to a map (not shown) with respect to the thus-obtained target mean effective pressure Pe and engine speed Ne, the ECU 31 determines a fuel injection mode. For example, when target mean effective pressure Pe and engine speed Ne are both low, the compression-stroke injection mode is selected as a fuel injection mode, so that fuel is injected during a compression stroke. When target mean effective pressure Pe or engine speed Ne increases, the intake-stroke injection mode is selected as a fuel injection mode, so that fuel is injected during an intake stroke. On the basis of target mean effective pressure Pe and engine speed Ne, a target air-fuel ratio (target A/F) is set so as to serve as a target of control for the corresponding fuel injection mode. On the basis of this target A/F, an appropriate amount of fuel to be injected is determined.

[0035] As in the case of an ultralean combustion operation in a lean mode, when exhaust gas assumes a lean air-fuel ratio; i.e., the form of an oxygen-excessive atmosphere, the NOx catalyst 15 of the exhaust-purifying catalyst device 13 occludes NOx contained in exhaust, in the form of a nitrate to thereby purify exhaust. When the oxygen concentration of exhaust gas lowers until exhaust gas assumes a stoichiometric air-fuel ratio or a rich air-fuel ratio, a nitrate occluded. on the NOx catalyst 15 and CO contained in exhaust react to produce a carbonate, thereby releasing NOx from the NOx catalyst 15. Accordingly, as occlusion of NOx onto the NOx catalyst 15 progresses, the oxygen concentration of exhaust is decreased through shift of the air-fuel ratio toward the rich side or through injection of additional fuel so as to supply CO, thereby releasing and reducing NOx occluded on the NOx catalyst 15 and thus maintaining the NOx-occluding function of the NOx catalyst 15.

[0036] The ECU 31 includes NOx-releasing means 32 for releasing NOx from the NOx catalyst 15 through lowering of the oxygen concentration of exhaust (establishment of a low-oxygen-concentration atmosphere of exhaust). The NOx-releasing means 32 causes occluded NOx to be released from the NOx catalyst 15 and reduced (NOx purge) in response to an instruction to release NOx from the NOx catalyst 15 (regeneration instruction). The NOx-releasing means 32 has a regeneration function composed of a rich purge function and a stoichiometric feedback (S-F/B) purge function. In execution of NOx purge, the rich purge function establishes a rich air-fuel ratio in exhaust for a first predetermined period of time, and subsequently the stoichiometric feedback purge function establishes a near stoichiometric air-fuel ratio (a stoichiometric air-fuel ratio or an air-fuel ratio slightly richer than the stoichiometric air-fuel ratio) for a second predetermined period of time.

[0037] The ECU 31 includes reducer-supplying means 33, which assumes the form of a pulse injection means. In order to additionally supply a reducer for reducing released NOx, the reducer-supplying means 33 causes additional fuel to be injected during the latter stage of an expansion stroke (or during the initial stage of an exhaust stroke) at a predetermined point of time (upon elapse of a predetermined period of time after a near stoichiometric air-fuel ratio is reached as a result of control of the air-fuel ratio to a rich air-fuel ratio; i.e., when the air-fuel ratio of exhaust gas is switched to a rich air-fuel ratio) during release of NOx effected by the NOx-releasing means 32.

[0038] At a predetermined point of time during release of NOx effected by the NOx-releasing means 32, the pulse injection means operates so as to effect injection of additional fuel during the latter stage of an expansion stroke (or during the initial stage of an exhaust stroke). However, the pulse injection means may be operated, irrelevant to operation of the NOx-releasing means 32, when the air-fuel ratio of the engine is switched to a stoichiometric air-fuel ratio or a rich air-fuel ratio. Specifically, upon an increase in load, such as upon acceleration or upon operation of an air conditioner or power steering, or when the air-fuel ratio of the engine is switched to a stoichiometric air-fuel ratio or a rich air-fuel ratio upon establishment of a negative pressure for a brake master vac., NOx is naturally released without operation of the NOx-releasing means 32. In this case, the pulse injection means may be operated during the

latter stage of an expansion stroke (or during the initial stage of an exhaust stroke) so as to inject additional fuel.

[0039] Basic operation of the above-described exhaust purifier will be described with reference to FIG. 3.

[0040] As in the case of an ultralean combustion operation in a lean mode, when exhaust gas assumes a lean air-fuel ratio; i.e., the form of an oxygen-excessive atmosphere, the NOx catalyst 15 of the exhaust-purifying catalyst device 13 causes oxidation of NOx contained in exhaust, thereby producing a nitrate, whereby NOx is occluded to purify exhaust. When the oxygen concentration of exhaust gas lowers until exhaust gas assumes a stoichiometric air-fuel ratio or a rich air-fuel ratio, a nitrate occluded on the NOx catalyst 15 and CO contained in exhaust react to produce a carbonate, thereby releasing NOx from the NOx catalyst 15. Accordingly, as occlusion of NOx onto the NOx catalyst 15 progresses; for example, when the cumulative time of lean operation exceeds a predetermined period of time, a regeneration instruction is sent to the NOx-releasing means 32. The NOx-releasing means 32 controls the air-fuel ratio to a stoichiometric air-fuel ratio or a rich air-fuel ratio so as to lower the oxygen concentration of exhaust, thereby causing release of NOx from the NOx catalyst 15 for maintaining the function of the NOx catalyst 15 (regeneration operation).

[0041] Specifically, as shown in FIG. 3(a), a target air-fuel ratio is gradually shifted to the rich-air-fuel-ratio side so that exhaust gas assumes the form of a low-oxygen-concentration atmosphere (operation of the NOx-releasing means 32). Upon shift of a target air-fuel ratio to the rich-air-fuel-ratio side, as represented by a dotted line in FIG. 3, supply of CO begins and the NOx catalyst 15 begins to release NOx according to the properties of noble metals carried thereon immediately after the NOx-releasing means 32 starts an NOx release operation; i.e., at a near stoichiometric air-fuel ratio. Since the amount of reducers (residual CO, HC, etc.) is not sufficient for reducing released NOx, the amount of released NOx becomes greater than that of NOx to be reduced. As a result, an unreduced portion of NOx released from the NOx catalyst 15 is released into the atmosphere.

[0042] Thus, in order to additionally supply a reducer for reducing released NOx during regeneration operation by the reducer-supplying means 33, as shown in FIG. 3, a drive pulse is generated so as to inject additional fuel (pulse injection) through operation of the fuel injection valve 4, at a near stoichiometric ratio and in addition to main fuel injection during a compression stroke or intake stroke; specifically, during or after an expansion stroke, preferably during the latter stage of an expansion stroke (or during the initial stage of an exhaust stroke). Pulse injection of such timing is preferred, since such pulse injection does not contribute to combustion and is thus less likely to affect engine output and can supply unburned HC (reducer). The amount of additional fuel to be injected is determined according to the amount of released NOx.

[0043] Thus, as represented with a solid line in FIG. 3(b), an additionally supplied reducer reduces NOx, thereby suppressing the amount of NOx to be released into the atmosphere. Accordingly, release of NOx and CO into the atmosphere can be suppressed, thereby preventing a problem of released NOx being emitted into the atmosphere.

[0044] Since the basic example is described here, a description for the above-mentioned stoichiometric feedback purge function of the NOx-releasing means 32 is omitted.

[0045] Supply of additional fuel for adding a reducer is set during a period between completion of combustion and completion of exhaust. Through supply of additional fuel during or after an expansion stroke, preferably during the latter stage of an expansion stroke (or during the initial stage of an exhaust stroke) as described above, the volume of the combustion chamber 5 becomes sufficiently large, and an exhaust valve opens immediately after supply of additional fuel to thereby generate a gas flow. Thus, no fuel adheres to the spark plug 3.

[0046] Preferably, noble metals to be carried on the NOx catalyst 19 are selected appropriately so as to minimize the difference between an NOx-releasing rate (the amount of NOx to be released) and an NOx-reducing rate (the amount of NOx to be reduced), thereby reducing the amount of fuel to be additionally injected.

[0047] Specific operation of the above-described exhaust purifier will be described in detail with reference to FIGS. 4 to 13. In the present embodiment, an NOx purge is performed in the following manner: a rich purge is performed for a first predetermined period of time; a stoichiometric feedback (S-F/B) purge is performed for a second predetermined period of time; and a pulse injection is combined with the rich purge and S-F/B purge.

[0048] Next will be described the basic idea of NOx release-and-reduction control, which involves a rich purge and a stoichiometric feedback (S-F/B) purge combined with a pulse injection. FIG. 8 shows the effect of a rich-state continuation time on NOx release-and-reduction (NOx purge) performance. An upper portion of FIG. 8 is an imaginary diagram showing an NOx-releasing rate with a rich-mode continuation time during which an NOx purge is performed at a constant rich air-fuel ratio through supply of CO to the NOx catalyst 15. During the initial stage of NOx purge after start of a rich mode, the NOx-releasing rate is high, so that a large amount of NOx is released rapidly. Since CO serving as a reducer is mainly consumed for releasing NOx, a reducer is in short supply. As a result, a large amount of NOx is emitted without being reduced. Even when a larger amount of CO is supplied, through an increase in the degree of a rich state, in order to supply a reducer for reducing NOx which would otherwise be emitted without being reduced, the amount of NOx released from the NOx catalyst 15 increases accordingly, and thus the NOx-releasing rate increases. Thus, a reducer is in short supply after all. To cope with this problem,

additional fuel is injected through pulse injection so as to supply unburned fuel; i.e., HC, to the catalyst. Since HC hardly contributes to release of NOx, supply of HC does not increase the NOx-releasing rate. Accordingly, released NOx can be reduced without involving an increase in the amount of released NOx. That is, through adjustment of the amount of pulse injection, the NOx-releasing rate can be balanced with the NOx-reducing rate, thereby suppressing emission of unreduced NOx.

[0049] After a certain period has elapsed after start of the rich mode, the NOx-releasing rate decreases. If the constant rich air-fuel ratio is maintained, CO serving as a reducer will become excessive, and thus a large amount of CO will be emitted without being used for reduction. Since CO is supplied excessively in a region of a low NOx-releasing rate, the degree of the rich state may be lowered such that a stoichiometric air-fuel ratio or a slightly rich air-fuel ratio is established, so as to reduce the supply of CO. Thus, emission of CO without use for reduction can be suppressed.

[0050] As described above, through combination of a rich purge and an S-F/B purge and further a pulse injection, an NOx purge can be carried out while minimizing emission of relevant exhaust gas components.

[0051] According to the present embodiment, in the case of the degree of deterioration of the NOx catalyst 15 having increased, when a rich purge is performed for catalytic regeneration, the NOx-releasing rate is initially high; consequently, a large amount of NOx is transiently released from the NOx catalyst 15. Subsequently, since release of NOx in a region of low NOx-releasing rate (a region in which an NOx purge is performed while a stoichiometric air-fuel ratio or a slightly rich air-fuel ratio is maintained) is time-consuming, the second predetermined period of time during which an S-F/B purge is performed is rendered relatively long (correction means). Thus, release of NOx consumes a greater amount of time as compared with the case of a low degree of deterioration of the NOx catalyst 15. However, NOx can be sufficiently reduced while suppressing impairment of fuel economy and release of reducers (unburned HC, CO, etc.) into the atmosphere.

[0052] The above-described NOx release-and-reduction control (NOx purge control) will be described with reference to flowcharts of FIGS. 4 and 5 and timing charts of FIGS. 6 and 7. FIG. 6 shows a state in which the degree of deterioration of the NOx catalyst 15 is low. FIG. 7 shows a state in which the degree of deterioration of the NOx catalyst 15 is high. FIGS. 6(a) and 7(a) show a state of NOx concentration (corresponding to an NOx-releasing rate) as measured downstream of the NOx catalyst 15. FIGS. 6(b) and 7(b) show a state of the air-fuel ratio and a state of a drive pulse of the fuel injection valve 4.

[0053] As shown in FIG. 4, in step S1, a judgment is made as to whether or not the temperature T'of the three-way catalyst 16 is greater than or equal to Ts (estimation from exhaust temperature as detected by means of the high-temperature sensor 14). When the temperature T of the three-way catalyst 16 is judged to be greater than or equal to Ts (i.e., it is judged that the temperature of the three-way catalyst 16 has reached the activation temperature Ts so that NOx purged from the occludent NOx catalyst 15 can be reduced), control proceeds to step S2. In step S2, a judgment is made as to whether or not the lean-mode continuation time Lt is greater than or equal to the first predetermined period of time t1, or whether or not the lean-mode continuation time Lt is greater than or equal to the second predetermined period of time t2 and also whether or not the lean mode is to be switched to a stoichiometric mode. The first predetermined period of time t1 (lean-mode continuation time) is set to, for example, 30 seconds, by a method which will be described later. The first predetermined period of time t1 serves as a condition of judgment to be employed when operation in the lean mode is performed continuously. The second predetermined period of time t2 is set to, for example, 5 seconds, and serves as a condition of judgment to be employed when an engine is to be accelerated in the lean mode.

[0054] A procedure for setting the lean-mode continuation time for use in NOx purge control will be described below.

(1) When lean operation is continued, the NOx catalyst 15 is saturated with occluded NOx, followed by release of NOx into the atmosphere. Allowable breakthrough time is defined as a period of time between start of the lean operation and the time when the amount of released NOx has reached a regulatory amount. NOx purge control must be forcedly performed (forced NOx purge) so as to avoid performance of lean operation beyond the allowable breakthrough time. Thus, the lean-mode continuation time is desirably not greater than a predetermined value (see FIG. 9).

(2) As shown in FIG. 10, the temperature of the (three-way) catalyst lowers with the lean-mode continuation time. When the temperature of the catalyst lowers, the purification efficiency of the catalyst is impaired, resulting in an increased HC emission value. Thus, the lean-mode continuation time is preferably not greater than a predetermined value.

(3) During NOx purge, a lean air-fuel ratio is established during a period of time ranging from the lean state to the stoichiometric state (NOx purge dead-time). Therefore, during the NOx purge dead-time, NOx is not released, but fuel economy worsens since the degree of the lean state decreases. Thus, in the case where the frequency of NOx purge increases as a result of lessening of the lean-mode continuation time, the percentage of the NOx purge dead-time in relation to the entire NOx purge time increases, thus worsening fuel economy. Accordingly, the lean-mode continuation time is preferably not greater than a predetermined value (see FIG.

11).

[0055] Under the above-described conditions (1) to (3), the optimum lean-mode continuation time can be set. For example, the catalytic capacity, characteristics of the NOx catalyst 15, characteristics of the three-way catalysts, and a regulatory value on emission of HC have a certain effect on the lean-mode continuation time. Generally, as represented by a dotted line in FIG. 12, from the viewpoint of HC emission value as mentioned above in (2), the lean-mode continuation time is preferably not greater than about 40 seconds. As represented by a solid line in FIG. 12, from the viewpoint of fuel economy as mentioned above in (3), the lean-mode continuation time is preferably not less than about 20 seconds. Accordingly, the lean-mode continuation time is 20 seconds to 40 seconds, preferably 30 seconds. In actual operation, since acceleration and deceleration are involved, the steady-state operation (lean operation) is less likely to continue longer than such a lean-mode continuation time, raising no problem in actual use. The lean-mode continuation time may be variable depending on the amount of NOx flowing into the NOx catalyst 15; for example, may be mapped with respect to a vehicle speed. Also, the lean-mode continuation time may assume a substantially constant value.

[0056] In step S2, when either condition is established (in the case of YES), indicating establishment of the condition for starting NOx release-and-reduction control (NOx purge) by regenerating means so as to release occluded NOx from the occludent NOx catalyst 15 and to reduce released NOx, control proceeds to step S3. In step S3, in order to perform a rich purge so that exhaust gas assumes a rich air-fuel ratio for the first predetermined period of time, rich purge period of time A (first predetermined period of time) and pulse injection period of time B are set.

[0057] Rich purge period of time A is set on the basis of the product of an exhaust flow rate, for example, a mapped value of intake air volume and the degree of deterioration of the NOx catalyst 15, for example, a mapped value of travel distance (deterioration-detecting means). Rich purge period of time A is set to, for example, about 1 second to about 5 seconds. Rich purge period of time A is set in such a manner so as to be shortened up to about two-third as travel distance increases; i.e., as the degree of deterioration increases. Rich purge period of time A is shortened for the following reason. As the degree of deterioration of the NOx catalyst 15 increases, NOx release characteristics vary as shown in FIGS. 6(a) and 7(a); specifically, the amount of released NOx decreases in a region of high NOx-releasing rate, and thus NOx release time becomes short. Thus, shortening of rich purge period of time A is intended to suppress worsening of fuel economy and release of unburned HC and CO.

[0058] Pulse injection period of time B is set on the basis of the product of an exhaust flow rate, for example, a mapped value of intake air volume and the degree of deterioration of the NOx catalyst 15, for example, a mapped value of travel distance (deterioration-detecting means). Pulse injection period of time B is set to, for example, about 0.1 second to about 1 second. Pulse injection period of time B is set in such a manner so as to be shortened up to about one-half as travel distance increases; i.e., as the degree of deterioration increases. Pulse injection period of time B is shortened for the following reason. As mentioned above, as the degree of deterioration of the NOx catalyst 15 increases, NOx release characteristics vary; specifically, the amount of released NOx decreases in a region of high NOx-releasing rate, and thus a required amount of a reducer is small. Thus, shortening of pulse injection period of time B is intended to suppress worsening of fuel economy and release of unburned HC.

[0059] After rich purge period of time A and pulse injection period of time B are set in step S3, control proceeds to step S4. In step S4, a rich purge for rich purge period of time A is initiated (at ta in FIGS. 6 and 7) in order to render the air-fuel ratio rich (e.g., A/F = 12). At this time, ignition timing, intake air volume, fuel injection timing, target EGR opening, etc. are controlled appropriately so as to avoid the occurrence of a stepwise torque change between the lean mode and the rich purge mode. When the lean mode is to be switched to the rich purge mode, tailing of air-fuel ratio is performed so as to avoid a sharp change in air-fuel ratio, thereby diminishing a torque shock involved in the switching.

[0060] In step S5, a judgment is made as to whether or not the air-fuel ratio has become stoichiometric in the process of tailing of air-fuel ratio. When the air-fuel ratio is judged to be stoichiometric (predetermined timing), control proceeds to step S6. In step S6, additional injection of fuel for pulse injection period of time B is initiated (at tb in FIGS. 6 and 7; herein, called pulse injection). In the process of tailing of air-fuel ratio, when the air-fuel ratio passes a stoichiometric region and begins to enter a rich region, the CO concentration of exhaust gas increases rapidly, and occluded NOx is released rapidly in a large amount from the occludent NOx catalyst 15 (see FIGS. 4(a) and 7(a)). As a result, the amount of CO or HC serving as a reducer becomes insufficient.

[0061] Thus, pulse injection is performed at the timing of the air-fuel ratio becoming stoichiometric to thereby add a reducer. Preferably, pulse injection is performed at a point of time between the intermediate stage of an expansion stroke and the initial stage of an exhaust stroke, particularly during the latter stage of an expansion stroke. Through additional injection of fuel during the latter stage of an expansion stroke, unburned fuel (reducer) is supplied into the exhaust path and is used for reducing NOx released from the catalyst. Injection of fuel during an expansion stroke or during an exhaust stroke is less likely to have an effect on the output of the cylinder-injection engine 1.

[0062] As mentioned above, pulse injection is initiated

at the timing of the air-fuel ratio becoming stoichiometric. If pulse injection is initiated too early, since NOx is not much released from the NOx catalyst 15, injected unburned fuel (reducer) will not be not used for reduction of NOx, but is released into the atmosphere, causing an increase in HC emission. By contrast, if pulse injection is initiated too late, the amount of a reducer will become insufficient for reducing released NOx which is increasing rapidly, causing an increase in NOx emission.

[0063] After pulse injection is performed in step S6, control proceeds to step S7. In step S7, as shown in FIG. 5, a judgment is made as to whether or not the pulse injection period of time is greater than or equal to B. When the pulse injection period of time is judged to be less than B, control returns to step S6, and pulse injection is continued. When the pulse injection time is judged to be greater than or equal to B, control proceeds to step S8, where the pulse injection is ended. Subsequently, in step S9, a judgment is made as to whether or not the rich purge period of time is greater than or equal to A. When the rich purge period of time is judged to be greater than or equal to A, control proceeds to step S10, where the rich purge is ended.

[0064] After the rich purge is ended, in order to perform an S-F/B purge so as to establish a stoichiometric air-fuel ratio in exhaust, in step S11, S-F/B purge period of time C (second predetermined period of time) is set. The S-F/B purge may be performed so as to establish in exhaust a near stoichiometric air-fuel ratio; i.e., an air-fuel ratio slightly richer than a stoichiometric air-fuel ratio.

[0065] S-F/B purge period of time C is set on the basis of the product of the following thee values: the last lean-mode continuation time; an exhaust flow rate, for example, a mapped value of intake air volume; and the degree of deterioration of the NOx catalyst 15, for example, a mapped value of travel distance (deterioration-detecting means). S-F/B purge period of time C is set to, for example, 0% to 50% lean-mode continuation time. S-F/B purge period of time C is set in such a manner that the S-F/B purge period of time C lengthens (% increases) with travel distance or with the degree of deterioration. Specifically, a mapped value of intake air volume is set such that S-F/B purge period of time C becomes 10% to 30% lean-mode continuation time. The thus-set S-F/B purge period of time C is varied between 0 time and about 1.5 times according to travel distance (according to deterioration).

[0066] S-F/B purge period of time C is lengthened with the degree of deterioration of the NOx catalyst 15 for the following reason. As shown in FIGS. 6(a) and 7(a), as the degree of deterioration of the NOx catalyst 15 increases, releasing of NOx consumes time in a region of low NOx-releasing rate. Specifically, as deterioration of the NOx catalyst 15 progresses, NOx release time becomes short in a region of high NOx-releasing rate and becomes long in a region of low NOx-releasing rate. Accordingly, through prolongation of S-F/B purge period of time C, a reducer is supplied for a longer period of time than in the case of low degree of deterioration. As a result, even though releasing of NOx consumes time, NOx can be sufficiently released and reduced.

[0067] After S-F/B purge period of time C is set in step S11, control proceeds to step S12. In step S12, an S-F/B purge is performed for S-F/B purge period of time C (between tc and td in FIGS. 6 and 7). At this time, ignition timing, intake air volume, fuel injection timing, target EGR opening, etc. are controlled appropriately so as to avoid the occurrence of a stepwise torque change between the rich purge mode and the S-F/B purge mode. When the rich purge mode is to be switched to the S-F/B purge mode, so as to avoid a sharp change in air-fuel ratio, thereby diminishing a torque shock involved in the switching. In the case of the S-F/B purge being performed in a slight rich state, an integral-correction gain for use in stoichiometric feedback control may be set such that a gain for shift to the rich state is greater than that for shift to the lean state.

[0068] After the S-F/B purge is performed in step S12, control proceeds to step S13. In step S13, a judgment is made as to whether or not the S-F/B purge period of time is greater than or equal to C. When the S-F/B purge period of time is judged to be less than C, control returns to step S12, and the S-F/B purge is continued. When the S-F/B purge period of time is judged to be greater than or equal to C, control proceeds to step S14, where the S-F/B purge is ended.

[0069] FIG. 13 shows the effect of catalyst deterioration on the NOx-releasing rate; specifically, S-F/B purge period of time, rich purge period of time, and pulse injection period of time in the case where emission of relevant exhaust gas components during NOx purge is minimized. As also seen from FIG. 13, the S-F/B purge period of time must be lengthened with the degree of catalyst deterioration, indicating an increase in a portion of low NOx-releasing rate. By contrast, the rich purge period of time and the pulse injection period of time must be shortened, indicating a decrease in a portion of high NOx-releasing rate.

[0070] The above-described exhaust purifier functions in the following manner. When occluded NOx is to be released from the NOx catalyst 15 and to be reduced, a rich purge is performed for the first predetermined period of time, and subsequently an S-F/B purge is performed for the second predetermined period of time. In the case of the degree of deterioration of the NOx catalyst 15 having increased, the second predetermined period of time, during which the S-F/B purge is performed, is lengthened. In the case of the degree of deterioration of the NOx catalyst 15 having increased, when a rich purge is performed for catalytic regeneration, the NOx-releasing rate is initially high; consequently, a large amount of NOx is abruptly released from the NOx catalyst 15 in a transient manner. Subsequently, even though release of NOx in a region of low NOx-releasing rate becomes time-consuming, a reducer is sup-

plied for a longer period of time as compared to the case of a low degree of deterioration of the NOx catalyst 15. Further, in the case of the degree of deterioration of the NOx catalyst 15 having increased, time required for releasing NOx in a region of high NOx-releasing rate becomes short. Therefore, the first predetermined period of time, during which the rich purge is performed, and the pulse injection period of time are shortened. Thus, NOx is sufficiently released and reduced while suppressing impairment of fuel economy and the amount of unburned HC and CO to be released into the atmosphere, thereby reliably suppressing the amount of NOx to be released into the atmosphere.

[0071] According to the above-described embodiment, a judgment is made in step S2 as to whether or not the lean mode must be switched to the stoichiometric mode. Thus, even at the time of acceleration, rich purge, S-F/B purge, and pulse injection are performed. However, at the time of acceleration, since fuel injection is increased, the rich state is established, followed by stoichiometric operation. Thus, only the pulse injection may be performed. Further, in this case, the pulse injection period of time may be variable depending on the degree of increase in fuel injection for acceleration or the lean-mode continuation time. At a point of time when a stoichiometric air-fuel ratio is reached, the pulse injection may be started.

[0072] According to the above-described embodiment, switching of the lean mode to the rich purge mode is gradually performed. When the stoichiometric state is established during the air-fuel ratio being tailed from the lean state to the rich state, the pulse injection is started. However, when the lean mode is instantaneously switched to the rich purge mode; i.e., when tailing of the air-fuel ratio is not performed, the pulse injection may be started simultaneously with the switching.

[0073] According to the above-described embodiment, the three-way catalyst 16 is disposed downstream of the NOx catalyst 15. NOx released from the NOx catalyst 15 is reduced not only on the NOx catalyst 15 but also on the three-way catalyst 16. However, there may be employed the NOx catalyst 15 assuming the form of an integral, occludent three-way NOx catalyst having a sufficient NOx-reducing (three-way catalyst) function. In this case, the pulse injection is perfumed over a very short period to time, or may be omitted.

[0074] Further, according to the above-described embodiment, the exhaust purifier is applied to a spark ignition engine, in which fuel is injected directly into a combustion chamber. However, the present invention may be applied to a diesel engine or a spark-ignition lean-burn engine, in which fuel is injected into a suction pipe and the thus-formed mixture is introduced into a combustion chamber, so long as the occludent NOx catalyst 15 is employed for release and reduction of NOx. When the present invention is applied to an engine in which mixture is introduced into a combustion chamber, the reducer-supplying means may be adapted to inject additional fuel serving as an additional reducer into an exhaust path.

[0075] Even when the NOx catalyst 15 (catalyst device) is deteriorated, the above-described exhaust purifier for use in an internal combustion engine can reliably reduce NOx emission while suppressing worsening of fuel economy and release of unburned HC and CO during regeneration of the NOx catalyst 15.

[0076] Since NOx released from the NOx catalyst device is reduced by means of an added reducer, the internal combustion engine of the present invention does not encounter a problem in which released NOx is emitted into the atmosphere, thereby suppressing worsening of exhaust gas performance.

Claims

1. An exhaust purifier for use in an internal combustion engine, **characterized by** comprising:

   - an NOx catalyst device (15) disposed in an exhaust path (11) of the engine (1) and having a function for occluding NOx contained in exhaust at a lean air-fuel ratio in exhaust and releasing occluded NOx at a stoichiometric air-fuel ratio or a rich air-fuel ratio in exhaust, **characterized by**
   - reducer-supplying means (33) for supplying additional HC as a reducer for reducing NOx released from said NOx catalyst device (15) when an air-fuel ratio in exhaust is switched from a lean air-fuel ratio to a stoichimetric air-fuel ratio or a rich air-fuel ratio.

2. An exhaust purifier for use in an internal combustion engine as described in claim 1, **characterized by**

   - NOx-releasing means (32) for causing said NOx catalyst (15) to release NOx through switching an air-fuel ratio in exhaust from a lean air-fuel ratio to a stoichiometric air-fuel ratio or a rich air-fuel ratio,
   - wherein said reducer-supplying means (33) additionally supplies a reducer for reducing NOx which is released into the exhaust path at predetermined timing during said NOx-releasing means (32) operating.

3. An exhaust purifier for use in an internal combustion engine as described in claim 1 or 2, **characterized in that** said reducer-supplying means (33) operates at predetermined timing when exhaust gas assumes a near stoichiometric air-fuel ratio.

4. An exhaust purifier for use in an internal combustion engine as described in claim 1 or 2, **characterized in that** the engine (1) comprises an injection valve

(4) for injecting fuel directly into a combustion chamber (5), and said reducer-supplying means (33) additionally supplies a reducer through control of operation of the injection valve (4).

5. An exhaust purifier for use in an internal combustion engine as described in claim 2, **characterized in that** said NOx catalyst (15) occludes NOx contained in exhaust when exhaust gas assumes a lean air-fuel ratio to create an oxygen-excessive atmosphere, and releases occluded NOx when exhaust gas assumes a stoichiometric air-fuel ratio or a rich air-fuel ratio to create a low-oxygen-concentration atmosphere;

said NOx-releasing means (32) has a regenerative function for establishing a rich air-fuel ratio in exhaust gas for a first predetermined period of time and subsequently establishing a near stoichiometric air-fuel ratio for a second predetermined period of time when NOx occluded on said NOx catalyst (15) is to be released; and

said reducer-supplying means (33) operates when said NOx-releasing means (32) causes an air-fuel ratio in exhaust gas to be switched to a rich air-fuel ratio.

6. An exhaust purifier for use in an internal combustion engine as described in claim 4, **characterized in that** said reducer-supplying means (33) injects fuel during an expansion stroke or an exhaust stroke subsequent to a main injection effected by the injection valve (4).

7. An exhaust purifier for use in an internal combustion engine as described in claim 5, **characterized by** further comprising deterioration-detecting means for detecting a degree of deterioration of said NOx catalyst (15) and correction means for correcting the second predetermined period of time for the said regenerative function of said NOx-releasing means (32) so that the higher the degree of deterioration of said NOx catalyst (15) detected by said deterioration-detecting means is, the longer the second predetermined period of time for the said regenerative function of said NOx-releasing means (32) is.

8. An exhaust purifier for use in an internal combustion engine as described in claim 1 or 2, **characterized by** further comprising deterioration-detecting means for detecting a degree of deterioration of said NOx catalyst (15) and correction means for correcting the operating period of time for said reducer-supplying means (33) so that the higher the degree of deterioration of said Nox catalyst (15) detected by said deterioration-detecting means is, the shorter the operating period of time for said reducer-supplying means (33) is.

9. An exhaust purifier for use in an internal combustion engine as described in claim 1, **characterized in that** the reducer-supplying means (33) operates when CO is supplied to said NOx catalyst (15) as a result of switching the air-fuel ratio in exhaust of said engine (1) from a lean air-fuel ratio to a stoichiometric air-fuel ratio or a rich air-fuel ratio.

10. An exhaust purifier for use in an internal combustion engine as described in claim 2, **characterized in that** the reducer-supplying means (33) operates when CO is supplied to said NOx catalyst (15) by said NOx-releasing means (32).

Patentansprüche

1. Abgasreinigungsvorrichtung für eine Brennkraftmaschine, **dadurch gekennzeichnet, daß** sie enthält:

einen NOx-Katalysator (15), der in einem Abgasweg (11) der Maschine (1) angeordnet ist, und die Funktion hat, NOx zu binden, das in einem Abgas bei einem mageren Luftkraftstoffverhältnis im Abgas enthalten ist, und gebundenes NOx bei einem stöchiometrischen Luftkraftstoffverhältnis oder einem fetten Luftkraftstoffverhältnis im Abgas freizusetzen, **gekennzeichnet durch**

eine Reduktionsmittel-Zuführeinrichtung (33) zum Zuführen von zusätzlichem HC als Reduktionsmittel zum Reduzieren von NOx, das von der NOx-Katalysatorvorrichtung 15 freigesetzt wird, wenn ein Luftkraftstoffverhältnis im Abgas von einem mageren Luftkraftstoffverhältnis zu einem stöchiometrischen Luftkraftstoffverhältnis oder einem fetten Luftkraftstoffverhältnis umgeschaltet wird.

2. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 1, **gekennzeichnet durch**:

eine NOx-Freisetzeinrichtung (32) zum Bewirken, daß der NOx-Katalysator (15) NOx **durch** Umschalten eines Luftkraftstoffverhältnises im Abgas von einem mageren Luftkraftstoffverhältnis zu einem stöchiometrischen Luftkraftstoffverhältnis oder einem fetten Luftkraftstoffverhältnis freisetzt,

wobei die Reduktionsmittel-Zuführeinrichtung (32) zusätzlich ein Reduktionsmittel zum Reduzieren von NOx zuführt, das in den Abgasweg zu einem vorbestimmten Zeitpunkt freigesetzt wird, während die NOx-Freisetzeinrichtung (32) arbeitet.

3. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 1 oder 2, **dadurch gek nnzeichnet, daß** die Reduktionsmittel-Zuführeinrichtung (33) zu einem vorbestimmten Zeitpunkt arbeitet, wenn das Abgas ein beinahe stöchiometrisches Luftkraftstoffverhältnis annimmt.

4. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 1 oder 2, **dadurch gekennzeichnet, daß** die Maschine (1) ein Einspritzventil (4) enthält, um Kraftstoff direkt in eine Verbrennungskammer (5) zu spritzen, und die Reduktionsmittel-Zuführeinrichtung (33) zusätzlich ein Reduktionsmittel durch Steuerung des Betriebs des Einspritzventils (4) zuführt.

5. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 2, **dadurch gekennzeichnet, daß** der NOx-Katalysator (15) NOx bindet, das im Abgas enthalten ist, wenn das Abgas ein mageres Luftkraftstoffverhältnis annimmt, um eine sauerstoffreiche Atmosphäre zu erzeugen, und gebundenes NOx freisetzt, wenn das Abgas ein stöchiometrisches Luftkraftstoffverhältnis oder ein fettes Luftkraftstoffverhältnis annimmt, um eine sauerstoffarme Atmosphäre zu erzeugen;
wobei die NOx-Freisetzeinrichtung (32) eine regenerative Funktion hat, um ein fettes Luftkraftstoffverhältnis im Abgas für einer erste vorbestimmte Zeitperiode einzurichten, und anschließend ein beinahe stöchiometrisches Luftkraftstoffverhältnis für eine zweite vorbestimmte Zeitperiode einzurichten, wenn NOx, das auf dem NOx-Katalysator (15) gebunden ist, freigesetzt werden soll; und
die Reduktionsmittel-Zuführeinrichtung (33) arbeitet, wenn die NOx-Freisetzeinrichtung (32) bewirkt, daß ein Luftkraftstoffverhältnis im Abgas zu einem fetten Luftkraftstoffverhältnis umgeschaltet wird.

6. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 4, **dadurch gekennzeichnet, daß** die Reduktionsmittel-Zuführeinrichtung (33) Kraftstoff während eines Ausdehnungshubs oder eines Auspuffhubs nach der Haupteinspritzung einspritzt, die durch das Einspritzventil (4) ausgeführt wird.

7. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 5, **dadurch gekennzeichnet, daß** sie weiterhin enthält: eine Beeinträchtigungs-Detektoreinrichtung zum Erfassen eines Ausmaßes der Beeinträchtigung des NOx-Katalysators (15) und eine Korrektureinrichtung zum Korrigieren der zweiten vorbestimmten Zeitdauer für die regenerative Funktion der NOx-Freisetzeinrichtung (32) derart, daß je höher das Ausmaß der Beeinträchtigung des NOx-Katalysators (15) ist, das durch die Beeinträchtigungs-Detektoreinrichtung erfaßt wird, umso länger die zweite vorbestimmte Zeitdauer für die regenerative Funktion der NOx-Freisetzeinrichtung (32) ist.

8. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 1 oder 2, **dadurch gekennzeichnet, daß** sie weiterhin enthält: eine Beeinträchtigungs-Detektoreinrichtung zum Erfassen eines Ausmaßes einer Beeinträchtigung des NOx-Katalysators (15) und eine Korrektureinrichtung zum Korrigieren der Betriebszeitdauer für die Reduktionsmittel-Zuführeinrichtung (33) derart, daß je höher das Ausmaß der Beeinträchtigung des NOx-Katalysators (15) ist, die durch die Beeinträchtigungs-Detektoreinrichtung erfaßt wird, umso kürzer die Betriebszeitdauer der Reduktionsmittel-Zuführeinrichtung (33) ist.

9. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 1, **dadurch gekennzeichnet, daß** die Reduktionsmittel-Zuführeinrichtung (33) arbeitet, wenn CO dem NOx-Katalysator (15) infolge des Umschaltens des Luftkraftstoffverhältnisses im Abgas der Maschine (1) von einem mageren Luftkraftstoffverhältnis zu einem stöchiometrischen Luftkraftstoffverhältnis oder einem fetten Luftkraftstoffverhältnis zugeführt wird.

10. Abgasreinigungsvorrichtung für eine Brennkraftmaschine nach Anspruch 2, **dadurch gekennzeichnet, daß** die Reduktionsmittel-Zuführeinrichtung (33) arbeitet, wenn CO dem NOx-Katalysator (15) durch die NOx-Freisetzeinrichtung (32) zugeführt wird.

Revendications

1. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, **caractérisé en ce qu'il** comprend:

- un dispositif catalyseur à NOx (15) disposé dans un trajet d'échappement (11) du moteur (1) et ayant pour fonction de bloquer les NOx contenus dans l'échappement dans le cas d'un rapport air/carburant pauvre dans l'échappement, et de dégager les NOx bloqués dans le cas d'un rapport air/carburant stoechiométrique ou dans le cas d'un rapport air/carburant riche dans l'échappement, **caractérisé par**
- des moyens de fourniture de réducteur (33) pour fournir un hydrocarbure additionnel à titre de réducteur pour réduire les NOx dégagés depuis ledit dispositif catalyseur à NOx (15) lorsqu'on bascule le rapport air/carburant dans l'échappement depuis un rapport air/carburant

pauvre vers un rapport air/carburant stoechiométrique, ou un rapport air/carburant riche.

2. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, comme décrit dans la revendication 1, **caractérisé par** :

- des moyens de dégagement de NOx (32) pour amener ledit catalyseur à NOx (15) à dégager des NOx par commutation d'un rapport air/carburant dans l'échappement depuis un rapport air/carburant pauvre vers un rapport air/carburant stoechiométrique, ou un rapport air/carburant riche ;
- dans lequel lesdits moyens de fourniture de réducteur (33) fournissent additionnellement un réducteur afin de réduire les NOx qui sont dégagés dans le trajet d'échappement à une temporisation prédéterminée pendant le fonctionnement desdits moyens de dégagement de NOx (32).

3. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon l'une ou l'autre des revendications 1 et 2, **caractérisé en ce que** lesdits moyens de fourniture de réducteur (33) fonctionnent à une temporisation prédéterminée lorsque les gaz échappement adoptent un rapport air/carburant proche d'un rapport stoechiométrique.

4. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon l'une ou l'autre des revendications 1 et 2, **caractérisé en ce que** le moteur (1) comprend une valve d'injection (4) pour injecter du carburant directement dans une chambre de combustion (5), et **en ce que** lesdits moyens de fourniture de réducteur (33) fournissent additionnellement un réducteur via une commande de fonctionnement de la valve d'injection (4).

5. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon la revendication 2, **caractérisé en ce que** ledit catalyseur à NOx (15) bloque les NOx contenus dans l'échappement lorsque les gaz d'échappement adoptent un rapport pauvre air/carburant afin de créer une atmosphère excessive en oxygène pour produire une atmosphère à excès d'oxygène, et **en ce qu'**il dégage les NOx bloqués lorsque les gaz d'échappement adoptent une valeur air/carburant stoechiométrique, ou un rapport air/carburant riche pour créer une atmosphère à faible concentration d'oxygène ;
lesdits moyens de dégagement de NOx (32) ont une fonction de régénération pour établir un rapport air/carburant riche dans les gaz d'échappement pendant une première période prédéterminée et pour établir ensuite un rapport air/carburant pratiquement stoechiométrique pendant une deuxième période prédéterminée lorsqu'il s'agit de dégager les NOx bloqués sur ledit catalyseur à NOx (15); et
lesdits moyens de fourniture de réducteur (33) fonctionnent lorsque lesdits moyens de dégagement de NOx (32) provoquent la commutation du rapport air/carburant dans les gaz d'échappement vers un rapport air/carburant riche.

6. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon la revendication 4, **caractérisé en ce que** lesdits moyens de fourniture de réducteur (33) injectent du carburant pendant une course d'expansion ou pendant une course d'échappement ultérieure à une injection principale effectuée par la valve d'injection (4).

7. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon la revendication 5, **caractérisé en ce qu'**il comprend en outre des moyens de détection de détérioration pour détecter un degré de détérioration dudit catalyseur à NOx (15) et des moyens de correction pour corriger la deuxième période prédéterminée pour la fonction de régénération desdits moyens de dégagement de NOx (32), de sorte que plus le degré de détérioration dudit catalyseur à NOx (15) détecté par lesdits moyens de détection de détérioration est élevé, plus longue sera la deuxième période prédéterminée pour la fonction de régénération des moyens de dégagement de NOx (32).

8. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon l'une ou l'autre des revendications 1 et 2, **caractérisé en ce qu'**il comprend en outre des moyens de détection de détérioration pour détecter un degré de détérioration dudit catalyseur à NOx (15) et des moyens de correction pour corriger la période de fonctionnement pour lesdits moyens de fourniture de réducteur (33) de sorte que plus le degré de détérioration dudit catalyseur à NOx (15) détecté par lesdits moyens de détection de détérioration est élevé, plus courte sera la période de fonctionnement pour lesdits moyens de fourniture de réducteur (33).

9. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon la revendication 1, **caractérisé en ce que** les moyens de fourniture de réducteur (33) fonctionnent lorsque du CO est fourni audit catalyseur à NOx (15) en résultat de la commutation du rapport air/carburant dans l'échappement dudit moteur (1) depuis un rapport air/carburant pauvre vers un rapport air/carburant stoechiométrique ou vers un rapport air/carbu-

rant riche.

10. Purificateur d'échappement destiné à être utilisé dans un moteur à combustion interne, selon la revendication 2, **caractérisé en ce que** les moyens de fourniture de réducteur (33) fonctionnent lorsque du CO est fourni audit catalyseur à NOx (15) par lesdits moyens de dégagement de NOx (32).

FIG. 1

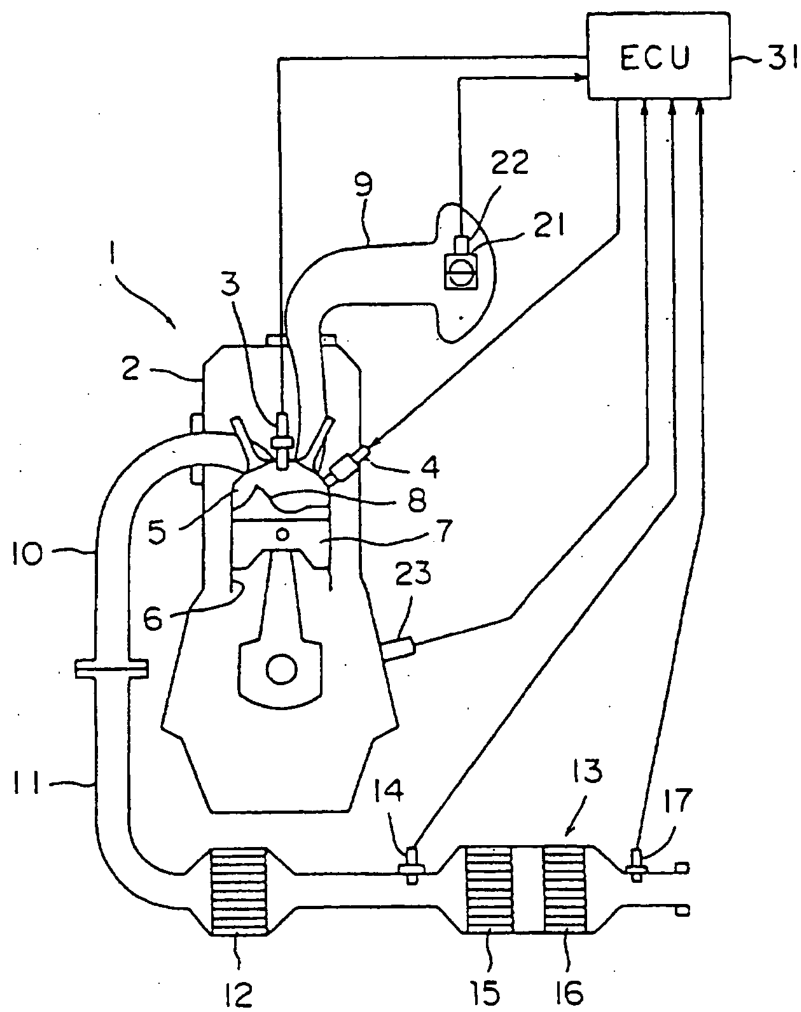


FIG. 2

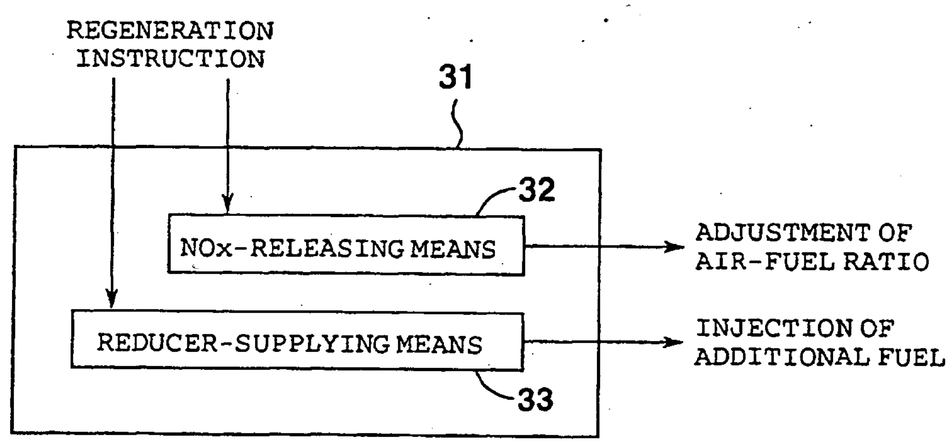

REGENERATION INSTRUCTION
31
32
NOx-RELEASING MEANS
ADJUSTMENT OF AIR-FUEL RATIO
REDUCER-SUPPLYING MEANS
INJECTION OF ADDITIONAL FUEL
33

FIG. 3

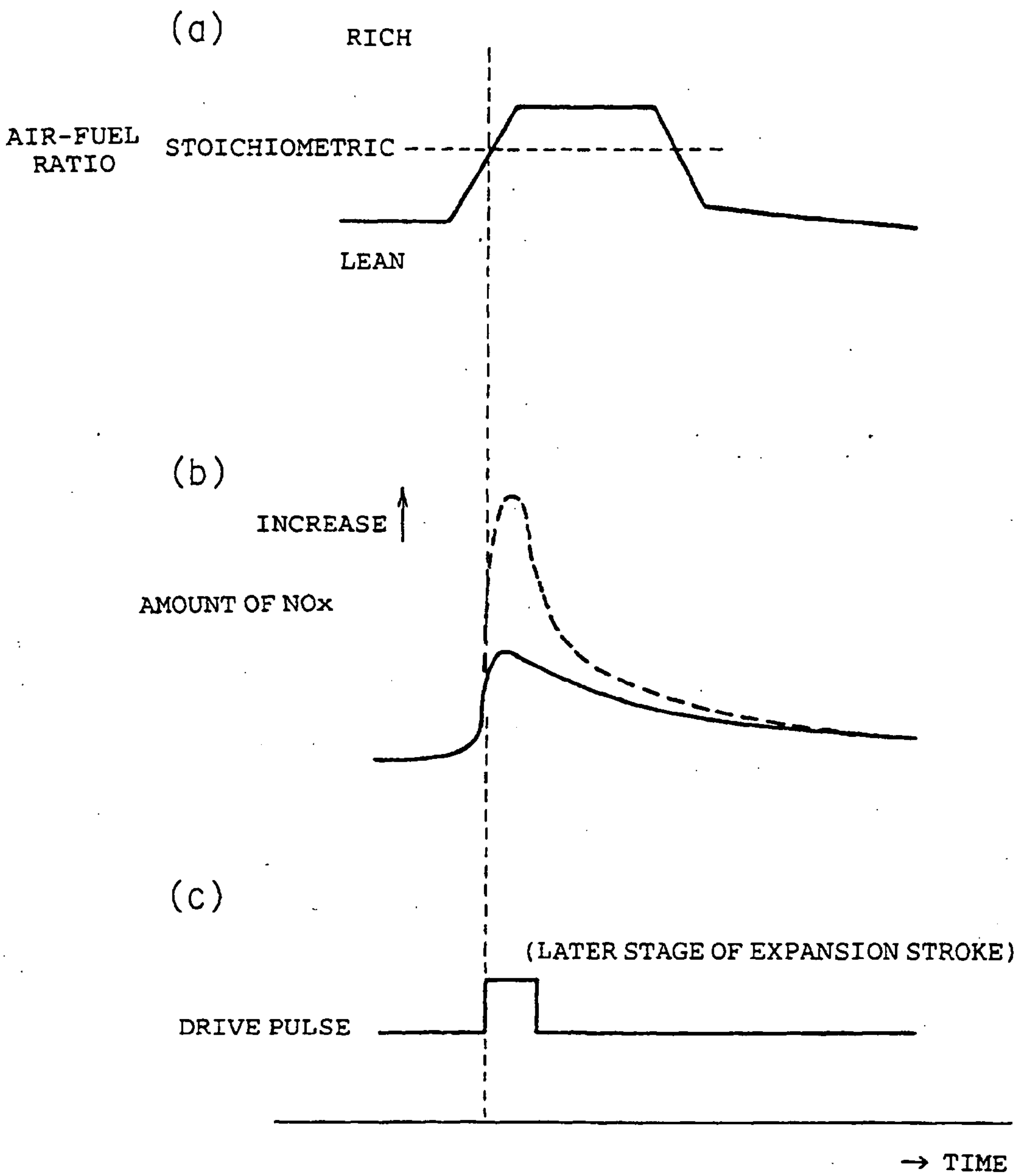

(a)
RICH
AIR-FUEL RATIO
STOICHIOMETRIC
LEAN
(b)
INCREASE
AMOUNT OF NOx
(c)
(LATER STAGE OF EXPANSION STROKE)
DRIVE PULSE
→ TIME

FIG. 4

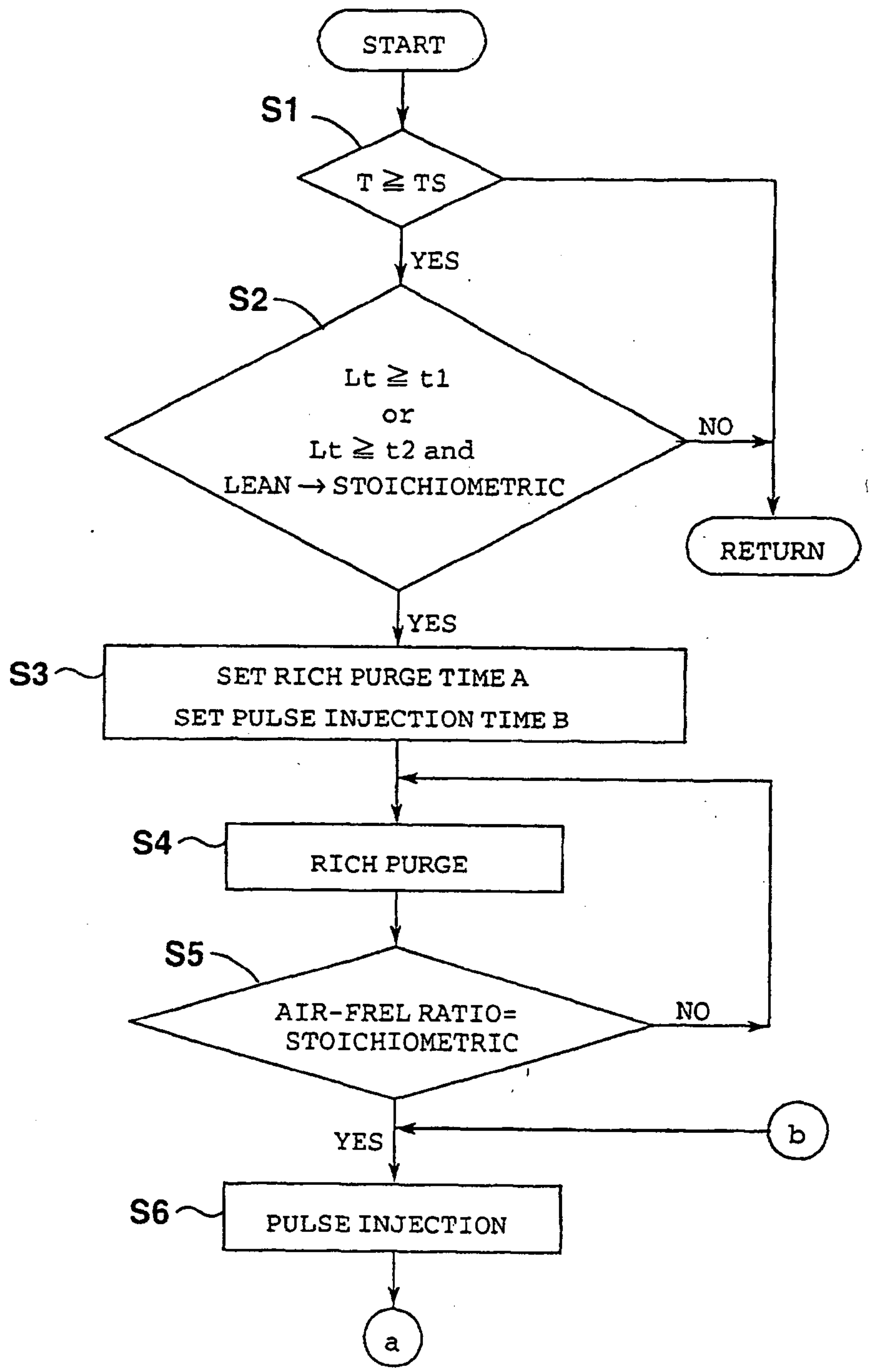

START
S1
T ≧ TS
YES
S2
Lt ≧ t1
or
Lt ≧ t2 and
LEAN → STOICHIOMETRIC
NO
RETURN
YES
S3
SET RICH PURGE TIME A
SET PULSE INJECTION TIME B
S4
RICH PURGE
S5
AIR-FREL RATIO=
STOICHIOMETRIC
NO
YES
b
S6
PULSE INJECTION
a

FIG. 5

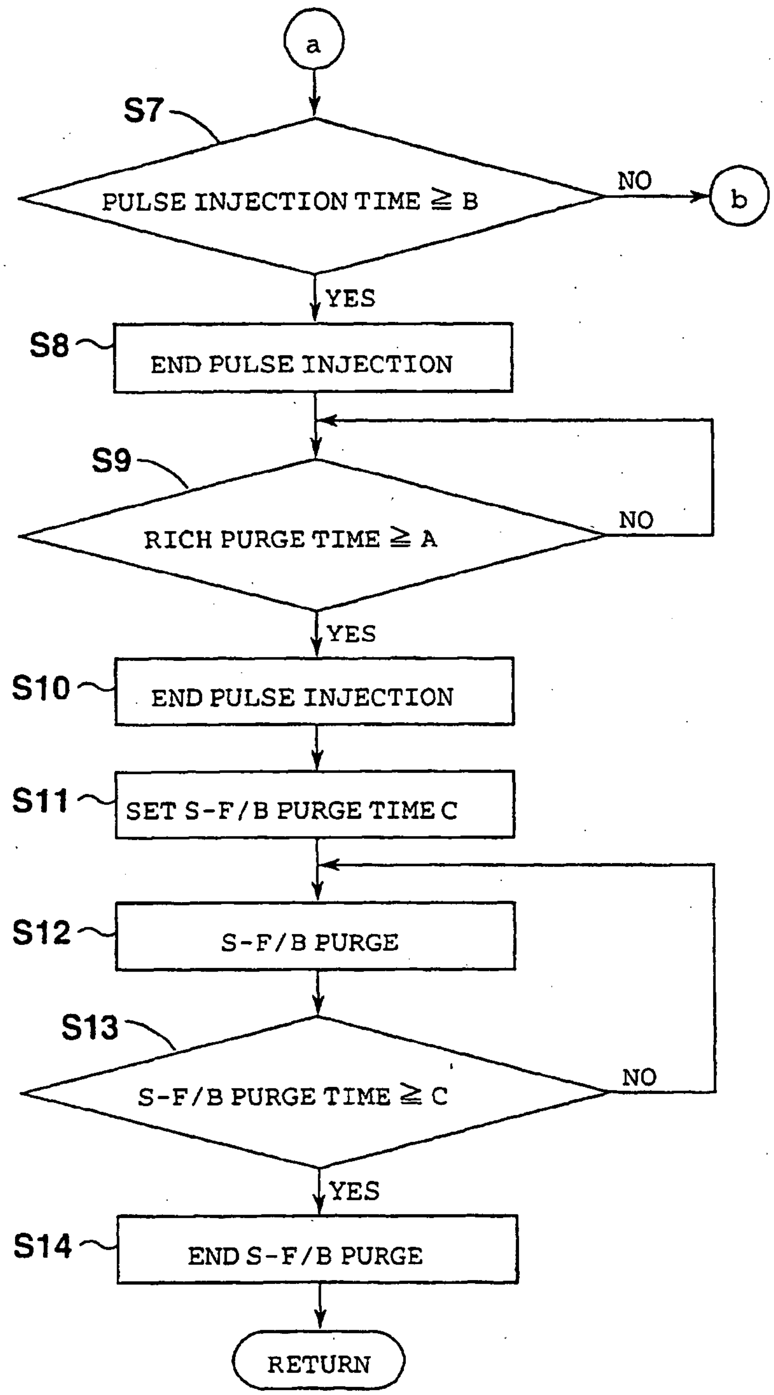

a
S7
PULSE INJECTION TIME ≧ B
NO
b
YES
S8
END PULSE INJECTION
S9
RICH PURGE TIME ≧ A
NO
YES
S10
END PULSE INJECTION
S11
SET S-F/B PURGE TIME C
S12
S-F/B PURGE
S13
S-F/B PURGE TIME ≧ C
NO
YES
S14
END S-F/B PURGE
RETURN

FIG. 6

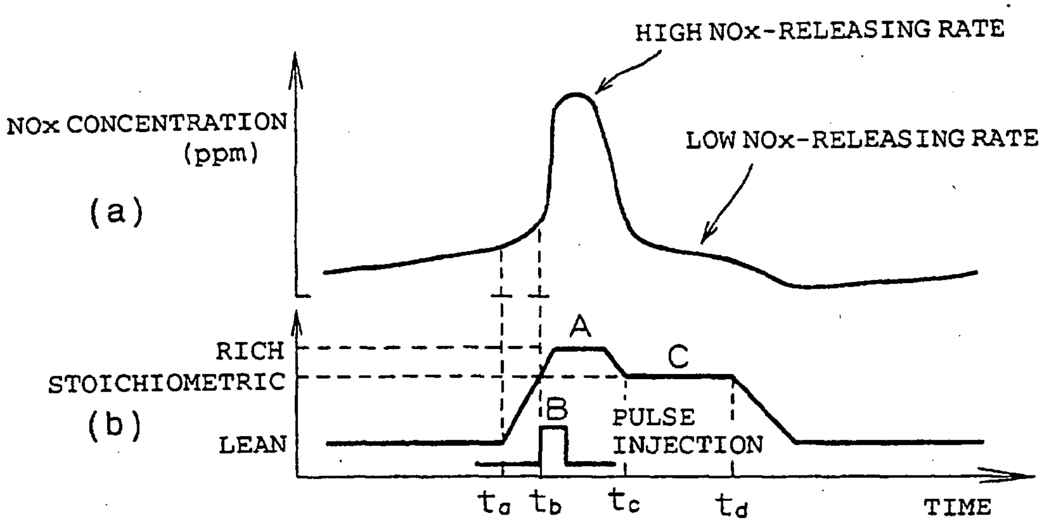

HIGH NOx-RELEASING RATE
NOx CONCENTRATION (ppm)
LOW NOx-RELEASING RATE
(a)
RICH
STOICHIOMETRIC
(b)
LEAN
A
C
B
PULSE INJECTION
t_a t_b t_c t_d
TIME

FIG. 7

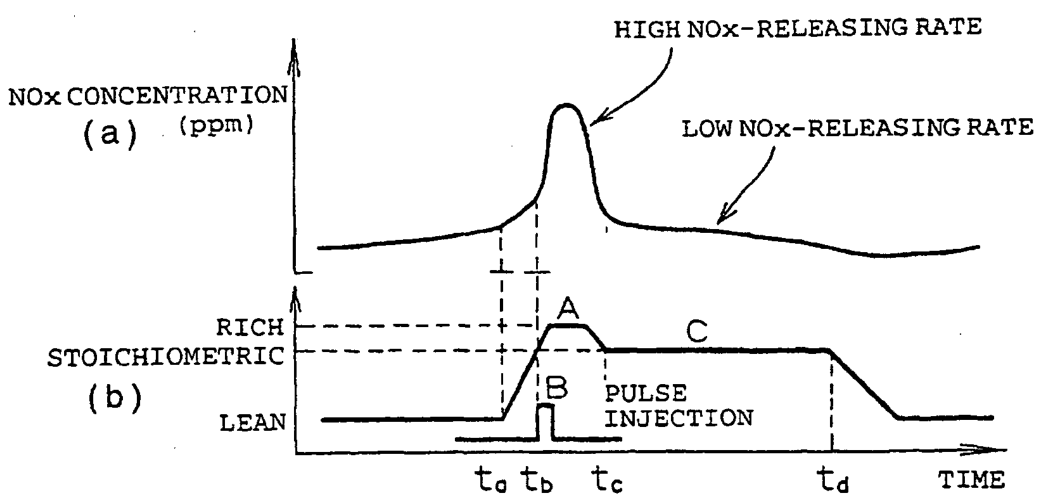

HIGH NOx-RELEASING RATE
NOx CONCENTRATION (ppm)
(a)
LOW NOx-RELEASING RATE
RICH
STOICHIOMETRIC
(b)
LEAN
A
C
B
PULSE INJECTION
t_a t_b t_c t_d
TIME

FIG. 8

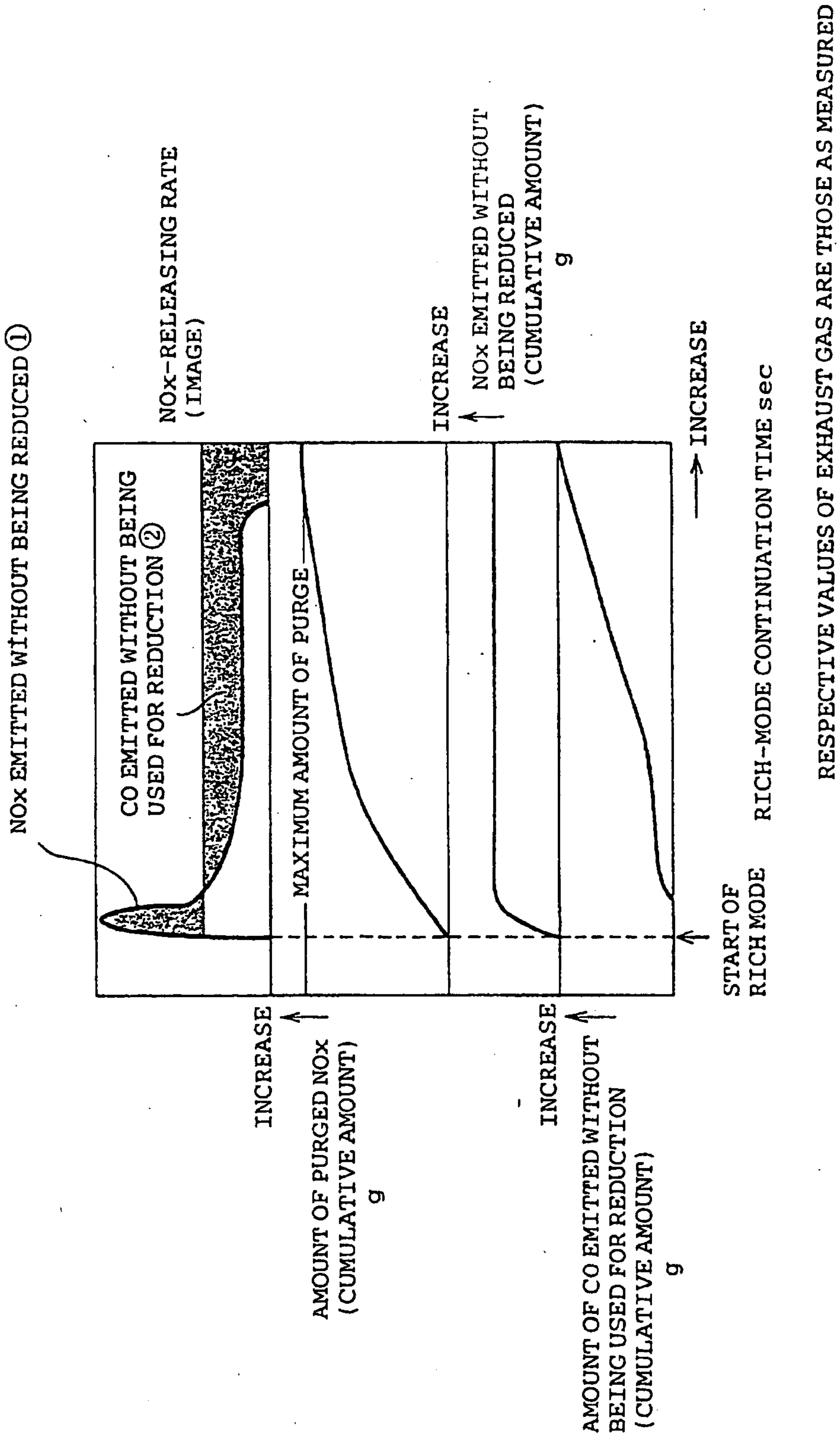

NOx EMITTED WITHOUT BEING REDUCED ①
CO EMITTED WITHOUT BEING USED FOR REDUCTION ②
NOx-RELEASING RATE (IMAGE)
MAXIMUM AMOUNT OF PURGE
INCREASE
AMOUNT OF PURGED NOx (CUMULATIVE AMOUNT) g
INCREASE
NOx EMITTED WITHOUT BEING REDUCED (CUMULATIVE AMOUNT) g
INCREASE
AMOUNT OF CO EMITTED WITHOUT BEING USED FOR REDUCTION (CUMULATIVE AMOUNT) g
START OF RICH MODE
INCREASE
RICH-MODE CONTINUATION TIME sec
RESPECTIVE VALUES OF EXHAUST GAS ARE THOSE AS MEASURED DOWNSTREAM OF EXHAUST PURIFIER 13

FIG. 9

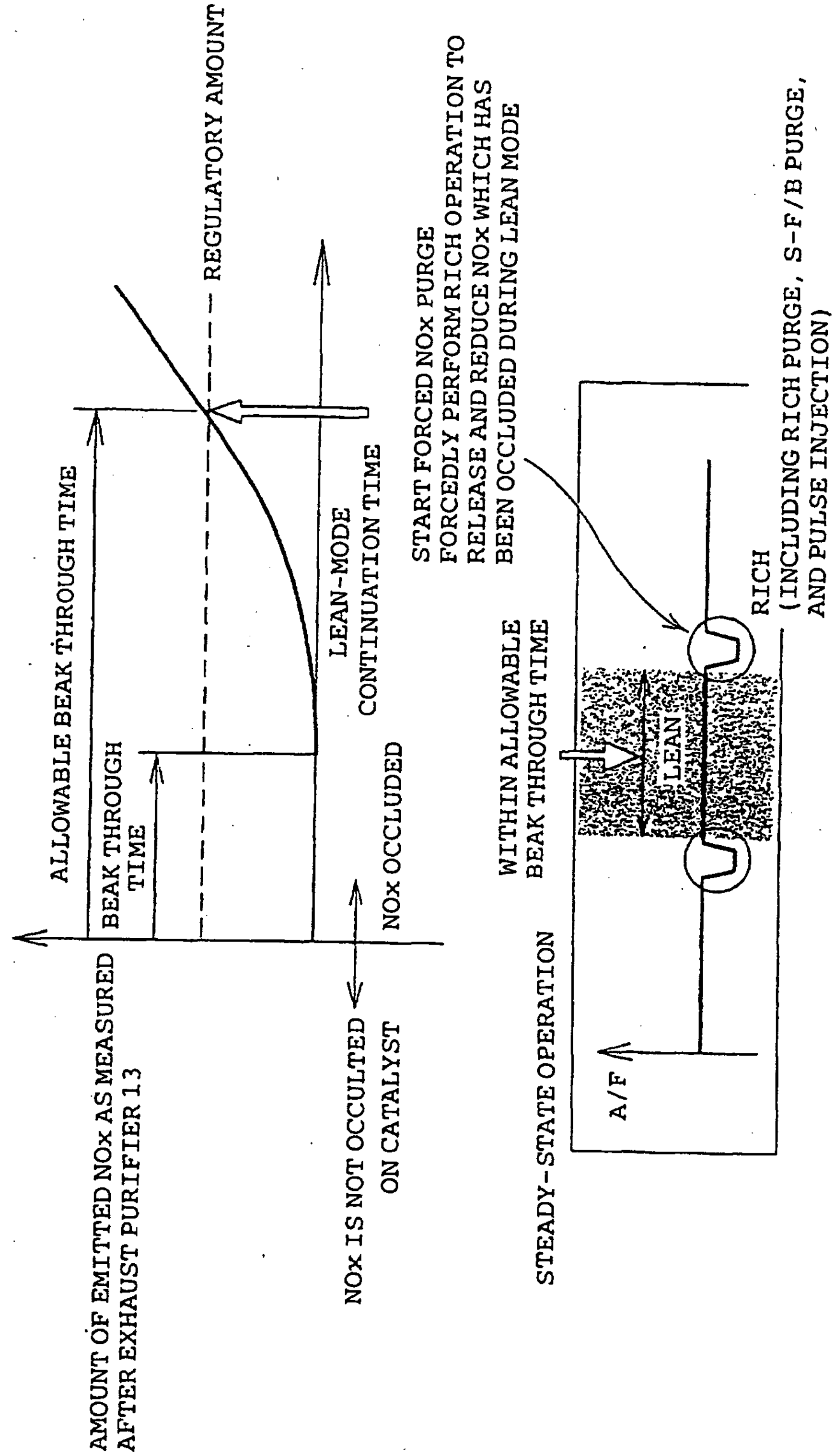
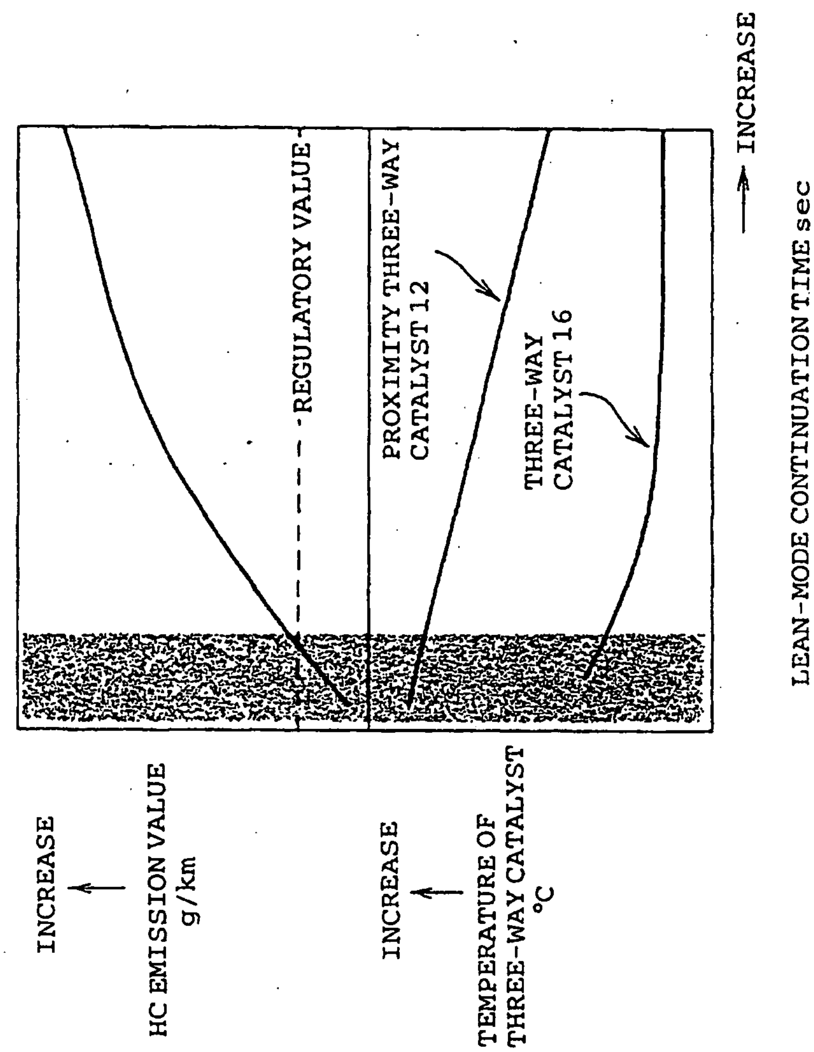

AMOUNT OF EMITTED NOx AS MEASURED AFTER EXHAUST PURIFIER 13
ALLOWABLE BEAK THROUGH TIME
BEAK THROUGH TIME
REGULATORY AMOUNT
LEAN-MODE CONTINUATION TIME
NOx IS NOT OCCULTED ON CATALYST
NOx OCCLUDED
STEADY-STATE OPERATION
A/F
WITHIN ALLOWABLE BEAK THROUGH TIME
LEAN
START FORCED NOx PURGE FORCEDLY PERFORM RICH OPERATION TO RELEASE AND REDUCE NOx WHICH HAS BEEN OCCLUDED DURING LEAN MODE
RICH (INCLUDING RICH PURGE, S-F/B PURGE, AND PULSE INJECTION)

FIG. 10



BEST AVAILABLE COPY

FIG. 11

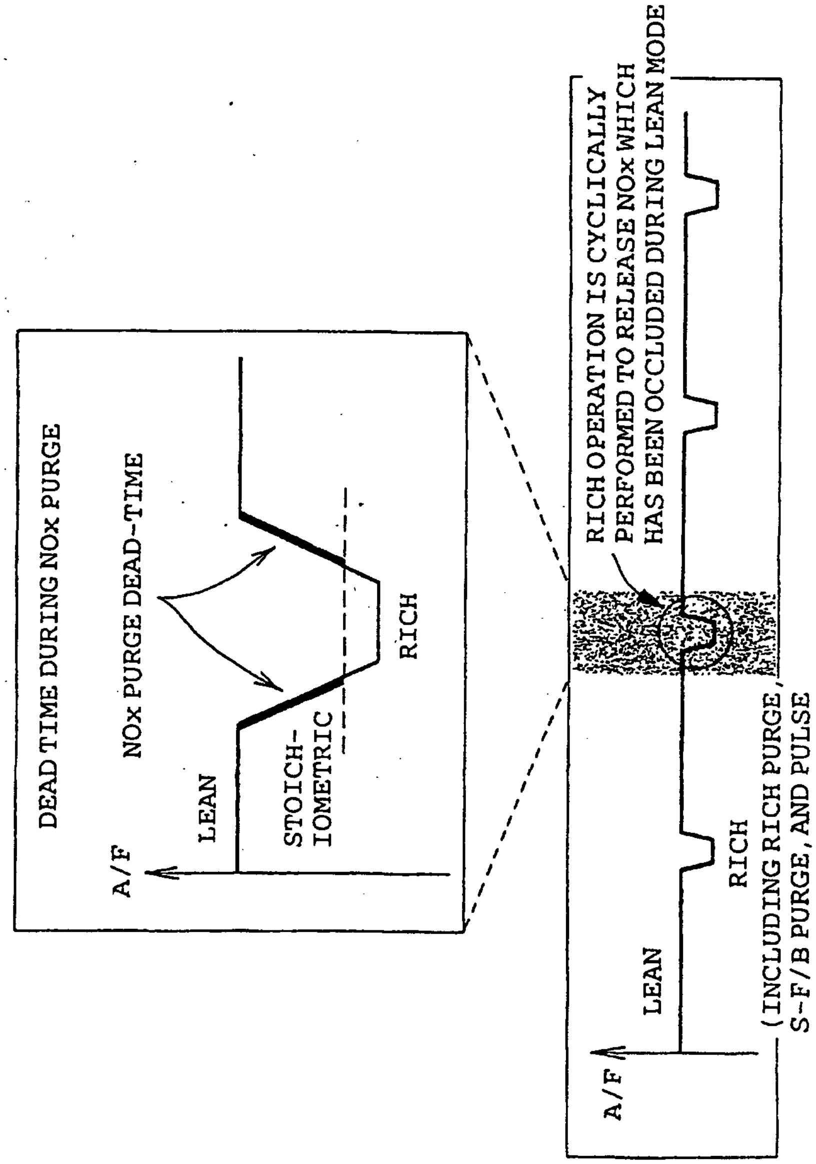

DEAD TIME DURING NOx PURGE
NOx PURGE DEAD-TIME
A/F
LEAN
STOICH-
IOMETRIC
RICH
RICH OPERATION IS CYCLICALLY PERFORMED TO RELEASE NOx WHICH HAS BEEN OCCLUDED DURING LEAN MODE
A/F
LEAN
RICH
(INCLUDING RICH PURGE, S-F/B PURGE, AND PULSE INJECTION)

FIG. 12

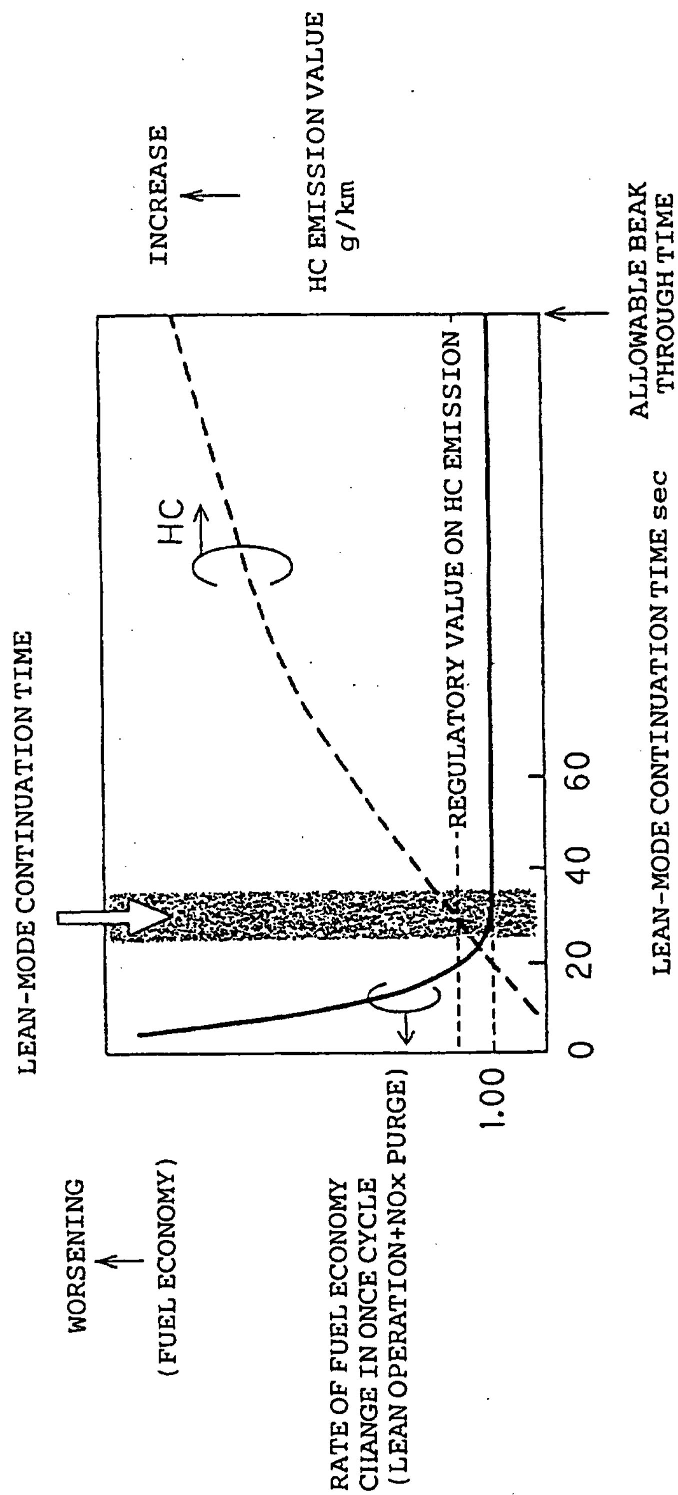
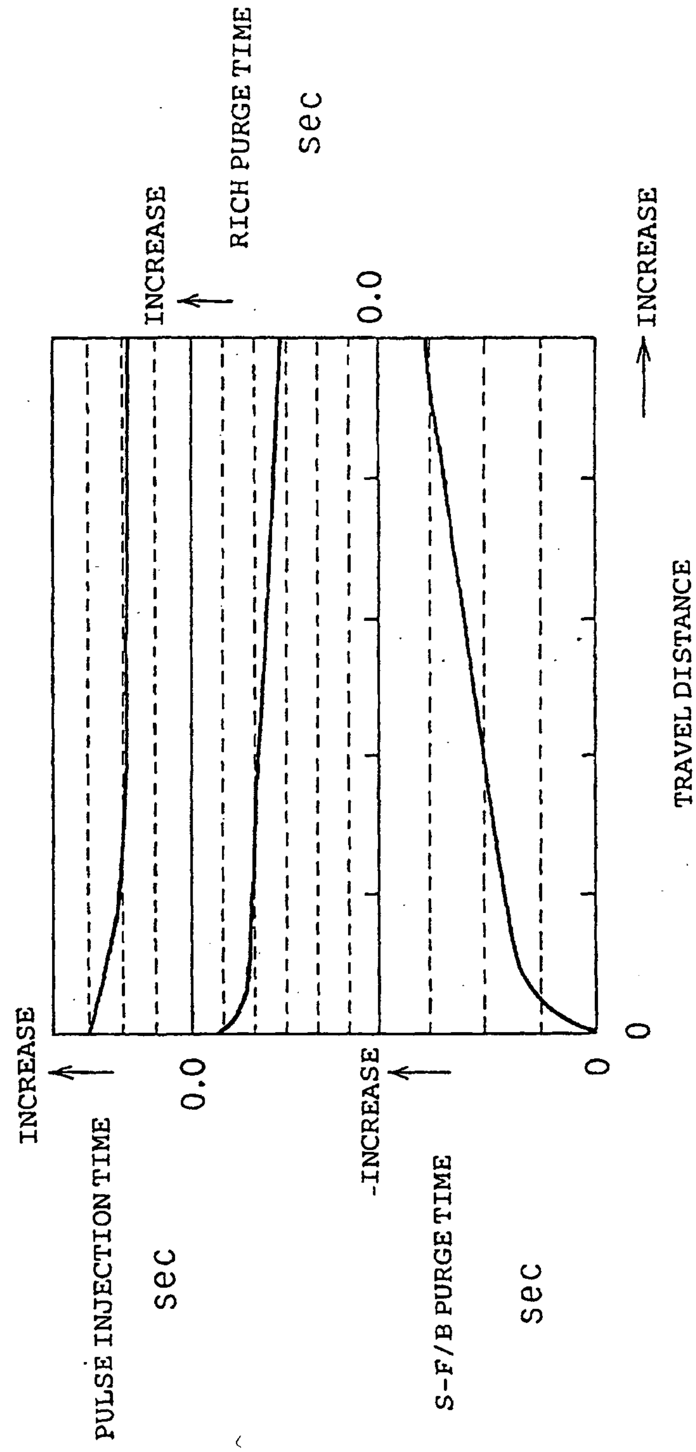

INCREASE
HC EMISSION VALUE
g/km
HC
REGULATORY VALUE ON HC EMISSION
ALLOWABLE BEAK
THROUGH TIME
LEAN-MODE CONTINUATION TIME
0
20
40
60
LEAN-MODE CONTINUATION TIME sec
1.00
WORSENING
(FUEL ECONOMY)
RATE OF FUEL ECONOMY
CIIANGE IN ONCE CYCLE
(LEAN OPERATION+NOx PURGE)

FIG. 13


PULSE INJECTION TIME
sec
INCREASE
0.0
RICH PURGE TIME
sec
INCREASE
0.0
S-F/B PURGE TIME
sec
-INCREASE
0
0
TRAVEL DISTANCE
INCREASE